IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

First Named Inventor	: Kevin Schulz et al.	Appeal No. ---
Appln. No.	: 09/457,816	
Filed	: December 9, 1999	Group Art Unit: 2652
For	: FLEXIBLE CIRCUIT	Examiner: B. Miller
Docket No.	: S01.12-0517	

SUBSTITUTE BRIEF FOR APPELLANT

Commissioner for Patents
Washington, D.C. 20231

I HEREBY CERTIFY THAT THIS PAPER IS BEING SENT BY U.S. MAIL, FIRST CLASS, TO THE ASSISTANT COMMISSIONER OF PATENTS, WASHINGTON, D.C. 20231, THIS 10th DAY OF June, 2002.
Christopher L. Holt
PATENT ATTORNEY

Sir:

This is an appeal from an Office Action dated December 3, 2001 in which pending claims were finally rejected.

REAL PARTY IN INTEREST

Seagate Technology LLC, a corporation organized under the laws of the state of Delaware, and having offices at 920 Disc Drive, Scotts Valley, California 95066, has acquired the entire right, title and interest in and to the invention, the application, and any and all patents to be obtained therefor, as set forth in the Assignment filed with the patent application and recorded on Reel 010687, Frame 0301.

RELATED APPEALS AND INTERFERENCES

There are no known related appeals or interferences that will directly affect or be directly affected by or have a bearing on the Board's decision in this appeal.

STATUS OF THE CLAIMS

Claims 1-20 were originally submitted. Claims 13, 14 and 16-20 were previously cancelled. All pending claims, namely claims 1-12 and 15, stand rejected. Claims 2-12 were finally rejected in the Office Action dated December 3, 2001. As will be explained below, Appellant believes that claim 1 was inadvertently omitted from that final rejection. The rejection of claims 1-12 and 15 is hereby appealed. A copy of claims 1-12 and 15 is attached hereto as Appendix A.

STATUS OF AMENDMENTS

No amendments were filed subsequent to the final rejection.

SUMMARY OF INVENTION

I. INTRODUCTION

The present invention generally pertains to disc storage devices. More specifically, the present invention pertains to disc drive units that incorporate flexible circuits.

II. BRIEF BACKGROUND

Disc drives are used for storing information, typically as magnetically encoded data, and more recently as optically encoded data, on a disc surface. A typical disc drive is shown in the drawing submitted herewith as Appendix B. A disc drive generally includes a load beam that supports a hydrodynamic air bearing (or slider) proximate a rotating magnetic disc. The load beam supplies a downward force that counteracts a hydrodynamic lifting force developed by the air bearing. The slider carries a magnetic transducer for communicating with individual positions on the rotating magnetic disc.

During disc drive operation, an electrical connection

must be maintained between the transducer, which is carried by an actively moving slider, and at least one signal processing component that is, generally speaking, remotely fixed in a stationary position. A flexible circuit or flex cable can be employed to provide a bendable electrical connection between active and stationary components.

Within the particularly sensitive environment of a disc drive, flexible circuit connections preferably do not significantly affect disc drive performance characteristics. As storage densities on disc recording media become higher, the performance characteristics of most all disc drive components, including the slider assembly, become more strict and tolerances are reduced. Therefore, as storage densities increase, it becomes even more important to reduce or eliminate any adverse effects that flexible circuit connections might have on disc drive performance.

III. CONCISE EXPLANATION OF THE CLAIMED INVENTION

The present invention generally provides a disc drive (e.g., 400) that includes at least one data storage disc (e.g., 322, 408) and a suspension assembly (e.g., 100, 200, 306). The suspension assembly includes a transducer head (e.g., 106, 210, 418) supported on an adjustable arm (e.g., 120, 330, 414). A flexible circuit (e.g., 104, 212, 340, 420) includes an electrically conductive element (e.g., 150, 222, 224, 252) laminated to a dielectric liquid crystal substrate (e.g., 140, 226, 254). The flexible circuit (e.g., 104, 212, 340, 420) is electrically connected to the transducer head (e.g., 106, 210, 418), which is configured to be carried proximate to a spinning data storage disc (e.g., 322, 408).

The present invention provides a disc drive (e.g., 400) that incorporates a specialized flexible circuit (e.g., 104, 212, 340, 420) for electrically connecting a transducer head (e.g.,

106, 210, 418) to a signal processing component. The specialized flexible circuit (e.g., 104, 212, 340, 420) generally comprises an electrically conductive element (e.g., 150, 222, 224, 252) and a dielectric liquid crystal substrate (e.g., 140, 226, 254) laminated to that conductive element. A general overview of the present invention can be found in Applicant's specification at page 4, line 9 through page 6, line 10.

Appellant has discovered that replacing traditional disc drive flexible circuits with this specialized flexible circuit reduces negative influences that a flex circuit might have on the flight characteristics of a transducer head during disc drive operation.

Appellant has discovered that incorporating a dielectric liquid crystal substrate design into the flexible circuits of disc drives enables reductions in undesirable radial forces, circumferential forces and/or yaw torque experienced by disc drive transducer heads during disc drive operation (e.g., see Applicant's specification at page 13, line 3-20). Further, Appellant has discovered that these specialized flexible circuits enable improved rise times and signal propagation at high data transfer rates within a disc drive system, as well as reductions in electrical dissipation, as compared to prior disc drive designs (e.g., see Applicant's specification at page 13, lines 21-33). Appellant has also discovered that the specialized flexible circuits enable a cleaner internal disc drive environment with fewer contamination particles to potentially compromise disc drive performance. Appellant has still further discovered that the specialized flexible circuits are also advantageous to application within a disc drive system because they are relatively inexpensive, enabling reductions in disc drive manufacturing costs. Finally, Appellant has discovered that thermoplastic characteristics associated with the specialized flexible circuits enable disc drive assembly to be simplified because such circuits

can simply be heat welded to a slider suspension assembly within a disc drive (e.g., see Applicant's specification at page 12, line 26 through page 13, line 2).

ISSUES

Whether claim 1 is anticipated by Boutaghou (U.S. Patent No. 5,796,556) under 35 U.S.C. §102(e); and whether claims 2-12 and 15 meet the requirements of non-obviousness under 35 U.S.C. §103, and thus, are patentable over Boutaghou ('556) in view of Lambert (U.S. Patent No. 5,795,162).

GROUPING OF CLAIMS

The following groupings of claims are made solely in the interest of consolidating issues and expediting this Appeal. No grouping of claims is intended to be, nor should be interpreted as being, any form of admission or a statement as to the scope or obviousness of any limitation.

GROUP 1: Claim 1

GROUP 2: Claims 2-12 and 15

ARGUMENT

I. INTRODUCTION

A. Prosecution of the Present Application

Appellant filed patent application Serial No. 09/457,816 on December 9, 1999, claiming priority to Provisional Application Serial No. 60/116,781 filed on January 22, 1999.

In the Office Action of June 29, 2001, claim 1 was rejected under 35 U.S.C. §102(b) in view of Boutaghou (U.S. Patent No. 5,796,556) and, alternatively, in view of Himes et al. (U.S. Patent No. 6,046,886). In Appellant's response dated August 27, 2001, Appellant claimed priority from the Himes '886 reference, thereby rendering moot the §102 rejection based on that reference. Also in Appellant's response filed August 27, 2001, Appellant made argument as to why claim 1 should be patentable over the Boutaghou '556 reference. The Office Action of December 3, 2001, however, completely omits claim 1 from consideration and comment. This is unusual because claim 1 was not (and has not since been) cancelled or withdrawn. Accordingly, Appellant assumes that the omission of claim 1 from the final rejection was an oversight on the part of the Examiner. Therefore, Appellant will assume that claim 1 is finally rejected for the reasons set forth in the earlier Office Action of June 29, 2001.

In the latest Office Action of December 3, 2001, claims 2-12 and 15 (on appeal) were finally rejected under 35 U.S.C. §103(a) as being unpatentable over Boutaghou ('556) in view of Lambert (U.S. Patent No. 5,795,162).

B. Prior Art

U.S. Patent No. 5,796,556 (Appendix C) to Boutaghou teaches a combined gimball flexure and electrical interconnect assembly for application within disc drive data storage systems. Column 1, lines 10-15. The assembly includes a load beam or suspension 12 and a flex cable 14. Column 2, lines 15-16. The flex cable 14 includes a plurality of electrical traces 20 and a

carrier 18 made of a material such as polyamide. Column 2, lines 20-22. The teachings of Boutaghou fail to provide any disclosure directed to a disc drive that incorporates a flexible circuit having a dielectric liquid crystal substrate.

U.S. Patent No. 5,795,162 (Appendix D) to Lambert teaches a radio frequency flex circuit transmission line and a related interconnection method for wireless communication systems. Column 1, lines 10-19. The teachings of Lambert include a radio frequency enabled flex circuit 36. Column 3, lines 56-65. Lambert teaches that, in order to optimize radio frequency signal characteristics, flex circuit 36 may incorporate a liquid crystal polymer material, namely a product called Vectran, as the incorporated dielectric material. Column 5, lines 40-56. However, the teachings of Lambert fail to provide any disclosure directed to a disc drive that incorporates a flexible circuit having a dielectric liquid crystal substrate.

II. THE REJECTION OF THE PENDING CLAIMS SHOULD BE REVERSED

A. Claim 1 Is Allowable Over Boutaghou

Claim 1 was rejected under 35 U.S.C. §102(b) as being anticipated by Boutaghou. The Office Action asserts that Boutaghou discloses a suspension assembly for use in a magnetic disc drive apparatus, wherein the disc drive includes a selection means for positioning a transducer and a conducting means for providing electrical connection between the transducer and an external circuit.

Appellant respectfully submits that proper construction of independent claim 1 must be done in accordance with 35 U.S.C. §112, paragraph 6. Section 2181 of the Manual of Patent Examining Procedure, provides guidance with respect to when claim language falls within 35 U.S.C. §112, paragraph six. Specifically, the M.P.E.P. sets out the following three-prong test:

1) the claim limitation must use the phrase "means for" or "step for";
2) the "means for" or "step for" must be modified by functional language; and
3) the phrase "means for" or "step for" must not be modified by structure, material or acts for achieving the specified function.

Independent claim 1 recites "a selection means for positioning a transducer" and "conducting means for providing electrical connection." Appellant respectfully notes that both of these elements are set forth as "means for". Further, in both cases, the functions provided after the preposition "for" require a proscribed functionality (positioning and providing). Therefore, both of the claimed elements recite "means for" as set forth in the first two prongs of the test. Appellant respectfully submits that these two prongs have been satisfied. Appellant respectfully submits that no structure for positioning or providing is set forth in independent claim 1 that would preclude applicability of 35 U.S.C. § 112, paragraph six. Thus, Appellant respectfully submits that the third prong of the test has also been satisfied.

35 U.S.C. § 112, sixth paragraph, states, in part, that a claim containing an element expressed as a means for performing a specified function without recital of structure, "shall be construed to cover the corresponding structure . . . described in the specification and equivalents thereof." The Federal Circuit has held that means-plus-function language in a claim must be construed according to the specification. See In re Donaldson Co., 29 U.S.P.Q.2d 1845 (Fed. Cir. 1994). The PTO may not disregard the structure disclosed in the specification corresponding to means-plus-function language when rendering a patentability determination. Id. at 1850.

In Donaldson, the Federal Circuit held that Section 112, Paragraph 6, applied to proceedings in the Patent Office. Particularly, the Federal Circuit held that Section 112, Paragraph 6, requires the Patent Office to construe a means plus function claim to cover the corresponding structure described in the specification.

In the present case, independent claim 1 recites a disc drive having a conducting means for providing electrical connection between a transducer and an external circuit. The structure of the conducting means is disclosed in Appellant's specification at least beginning on page 4, line 9, and extending through page 6, line 10, and can be located in other various locations throughout Appellant's specification. Although the rejection of claim 1 asserts that the disc drive suspension assembly of Boutaghou has its own means 20 for providing electrical connection between a transducer and an external circuit, there is no disclosure in the teachings of Boutaghou that suggests the specific structures set forth in Appellant's specification. The teachings of Boutaghou at least fail to provide any disclosure directed to a disc drive that teaches or suggests a flexible circuit having a dielectric liquid crystal substrate, as is specifically taught in Appellant's specification. Therefore, Appellant respectfully requests that the Board reverse the Examiner's rejection of claim 1.

B. Claims 2-12 and 15 Are Allowable Over The References Cited By The Examiner

Claims 2-12 and 15 were rejected under 35 U.S.C. §103(a) as being unpatentable over Boutaghou in view of Lambert.

It is respectfully pointed out that neither Boutaghou nor Lambert provide any disclosure directed to a disc drive that incorporates a flexible circuit having a dielectric liquid crystal substrate, as is claimed in independent claim 2. Presented with the inability of either reference to anticipate the invention of

claim 2, the Examiner, particularly in the Final Office Action, alternatively argues that the teachings of the two references can be combined so as to render obvious the invention of claims 2-12 and 15.

Appellant respectfully points out that the "fact that the claimed invention is within the capabilities of one of ordinary skill in the art is not sufficient by itself to establish *prima facie* obviousness. See §2143.01 of the Manual of Patent Examining Procedure. Even if the references relied upon do, in combination, teach all aspects of the claimed invention, that still is not sufficient to establish a *prima facie* case of obviousness without some objective reason to combine the teachings of the references. Ex parte Levengood, 28 USPQ2d 1300 (Bd. Pat. App. & Inter. 1993).

In the Final Office Action, the Examiner alleges a particular motivation to combine Boutaghou and Lambert. The Examiner essentially states that lacking any unobvious or unexpected results, the proposed combination would have been arrived at through routine engineering optimization and experimentation. It is respectfully submitted that this alleged motivation to combine is too speculative to support a denial of patentability in the present case. The Examiner's alleged motivation to combine is based on assumptions that are opinion-oriented and are not objectively reflected by the record.

It is fundamental that rejections under 35 U.S.C. §103 must be based on evidence comprehended by the language of that section. In re Grasselli, 713 F.2d 731, 739, 218 USPQ 769, 775 (Fed. Cir. 1983). The factual inquiry whether to combine references must be thorough and searching. Id. It must be based on objective evidence of record. In re Sang Su Lee, Case No. 00-1158, *7 (Fed. Cir., January 18, 2002)(Fed. Cir. BBS). In the present case, the only conclusion that can be reached from the alleged combinability of the references is the impermissible

hindsight gleaned from the present invention. See, e.g., Ex parte Haymond, 41 USPQ2d 1217, 1220 (BdPatApp&Int 1996)(the Examiner "may not, because he doubts that the invention is patentable, resort to speculation, unfounded assumptions or hindsight reconstruction to supply deficiencies in the factual basis.")

Simply stated, the present Office Actions do not provide any objective evidence that shows a motivation to combine the Boutaghou and Lambert references. Without such objective evidence, no *prima facie* case of obviousness has been made for claims 2-12 and 15. Therefore, this rejection is improper.

Further, in the Final Office Action itself, another rationale is provided as to why claims 2-12 and 15 are non-obvious and therefor patentable. As was previously noted, the Office Action essentially states that lacking any unobvious or unexpected results, the proposed combination would have been arrived at through routine engineering optimization and experimentation (emphasis added). Appellant respectfully submits that there are unobvious and unexpected results associated with incorporating a dielectric liquid crystal substrate design into the flexible circuits of disc drives. Several of these results are specifically described in Appellant's specification.

Appellant has discovered that adapting disc drives to include flexible circuits having a dielectric liquid crystal substrate leads to reductions in certain negative influences on transducer head motion during disc drive operation. For example, reductions in undesirable radial forces, circumferential forces and/or yaw torque are experienced. Further, Appellant has discovered that these specialized flexible circuits enable improved rise times and signal propagation at high data transfer rates within a disc drive system, as well as reductions in electrical dissipation, as compared to prior disc drive designs. See, e.g., Appellant's specification at page 13, lines 25-30. Appellant has also discovered that the specialized flexible

circuits enable a cleaner internal disc drive environment with fewer contamination particles to potentially compromise disc drive performance. Appellant has still further discovered that the specialized flexible circuits are also advantageous to application within a disc drive system because they are relatively inexpensive, enabling reductions in disc drive manufacturing costs. See, e.g., Appellant's specification at page 4, lines 1-21. Appellant has discovered that thermoplastic characteristics associated with the specialized flexible circuits enable disc drive assembly to be simplified because such circuits can simply be heat welded to a slider suspension assembly within a disc drive. Id. Finally, Appellant has discovered that the specialized circuits have sufficient mobility and improved resonant motion insensitivity so as to enable more precise positioning of disc drive transducer heads.

Simply stated, Appellant has discovered that incorporating a dielectric liquid crystal substrate design into the flexible circuits of disc drives enables a range of significant unobvious and unexpected improvements for disc drives, as compared to prior designs. Neither Boutaghou nor Lambert teach or suggest any of these unobvious and unexpected improvements. Therefore, the necessary motivation is lacking and this rejection is improper.

CONCLUSION

Appellant respectfully submits that independent claims 1 and 2 are neither taught nor suggested by the references cited by the Examiner. Also, Appellant respectfully submits that claims 3-15 and 17 are allowable as well by virtue of their dependency from allowable independent claim 2. Thus, Appellant respectfully requests that the Board reverse the Examiner and find all pending claims allowable.

Respectfully submitted,

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CLH

Appendix A

1. A disc drive comprising:

a selection means for positioning a transducer at a select point in space; and

a conducting means for providing electrical connectoin between the transducer and an external circuit.

2. A disc drive comprising:

at least one data storage disc;

a suspension assembly that includes a transducer head supported on an adjustable arm; and

a flexible circuit comprising an electrically conductive element and a dielectric liquid crystal substrate laminated to the conductive element, the flexible circuit being electrically connected to the transducer head and the transducer head being configured to be carried proximate a surface of a spinning data storage disc.

3. The disc drive of claim 2 wherein the conductive element comprises copper.

4. The disc drive of claim 2 wherein the dielectric liquid crystal substrate has a thickness less than about 0.001 inches.

5. The disc drive of claim 2 wherein the dielectric liquid crystal substrate has a thickness from about 0.0001 inches to about 0.0005 inches.

6. The disc drive of claim 2 wherein the dielectric liquid crystal substrate comprises a polyester.

7. The disc drive of claim 2 wherein the dielectric liquid crystal substrate has a dielectric constant from about 2.6 to about 3.0.

8. The disc drive of claim 2 wherein the dielectric liquid crystal substrate has a coefficient of thermal expansion from about 15 ppm/°C to about 19 ppm/°C.

9. The disc drive of claim 2 wherein the dielectric liquid crystal substrate has a coefficient of humidity expansion of less than about 4 ppm/% relative humidity.

10. The disc drive of claim 2 wherein the dielectric liquid crystal substrate has an elastic modulus from about 900 kpsi to about 1300 kpsi.

11. The disc drive of claim 2 further comprising a cover coating forming protective coating over at least a portion of the conductive element.

12. The disc drive of claim 2 wherein the liquid crystal substrate comprises a thermoplastic.

15. The disc drive of claim 2 wherein the data storage disc comprises a magnetic disc.

APPENDIX B

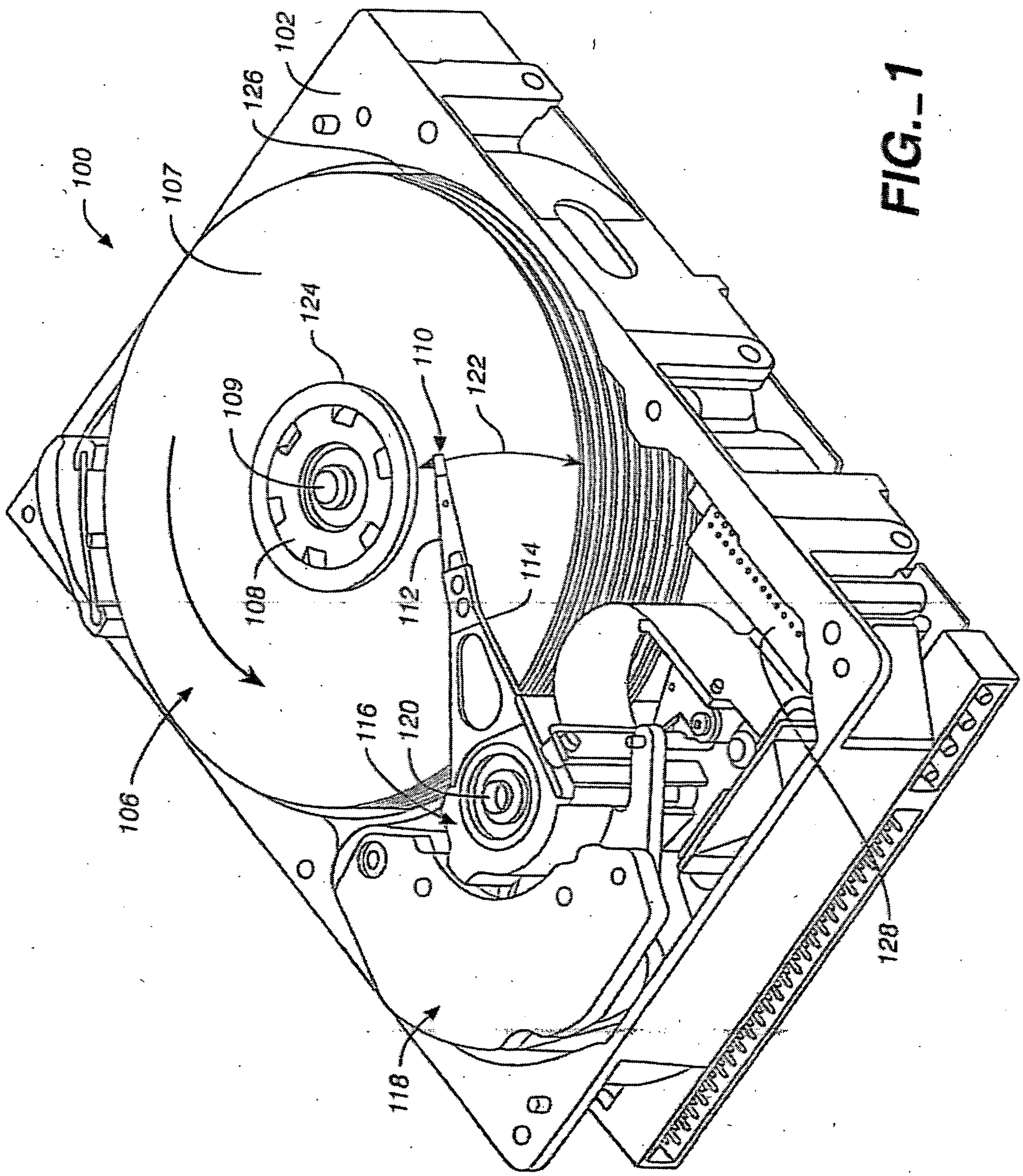

FIG._1

APPENDIX C

US005796556A

United States Patent [19]

Boutaghou

[11] Patent Number: 5,796,556

[45] Date of Patent: Aug. 18, 1998

[54] FLEX ON SUSPENSION DESIGN MINIMIZING SENSITIVITIES TO ENVIRONMENTAL STRESSES

[75] Inventor: Zine-Eddine Boutaghou, St. Paul, Minn.

[73] Assignee: Seagate Technology, Inc., Scotts Valley, Calif.

[21] Appl. No.: 926,579

[22] Filed: Sep. 4, 1997

Related U.S. Application Data

[62] Division of Ser. No. 712,276, Sep. 11, 1996, Pat. No. 5,701,218.

[60] Provisional application No. 60/021,205 Jul. 3, 1996.

[51] Int. Cl.^{6} G11B 5/60; G11B 21/21

[52] U.S. Cl. 360/104

[58] Field of Search 360/104

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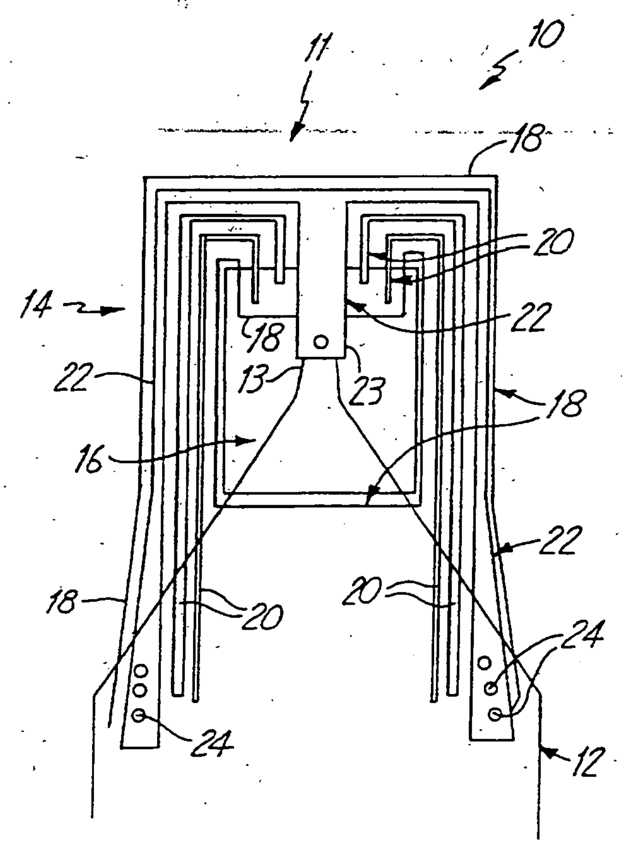
Primary Examiner—Robert S. Tupper
Attorney, Agent, or Firm—Westman, Champlin & Kelly, P.A.

[57] ABSTRACT

An improved flexure for supporting a magnetic head carrying slider is disclosed. The flexure includes a load beam and a flexible circuit. The flexible circuit includes a carrier material, a plurality of electrical traces supported by the carrier material for electrically coupling to the magnetic head carried by the slider, and a gimbal insert member supported by the carrier material in a position substantially coplanar with the plurality of electrical traces. The gimbal insert member is mechanically coupled to the load beam and to the slider such that the gimbal insert member supports the slider for gimbaled motion relative to the load beam.

7 Claims, 2 Drawing Sheets



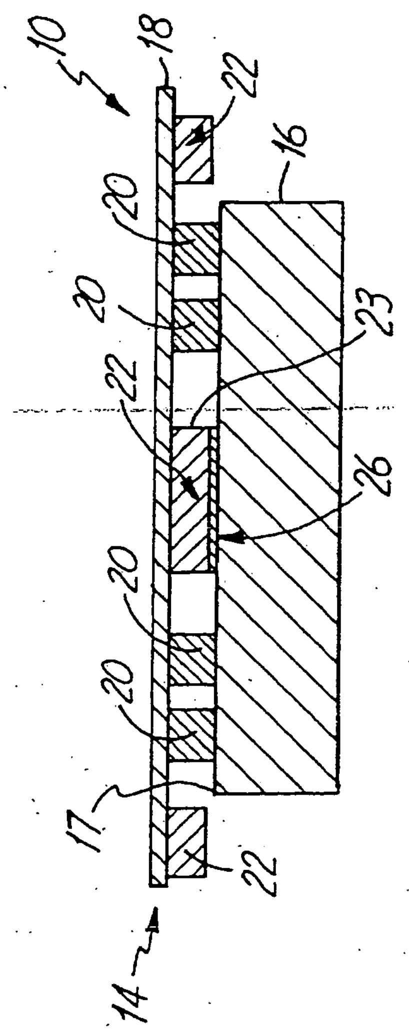

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Fig. 2

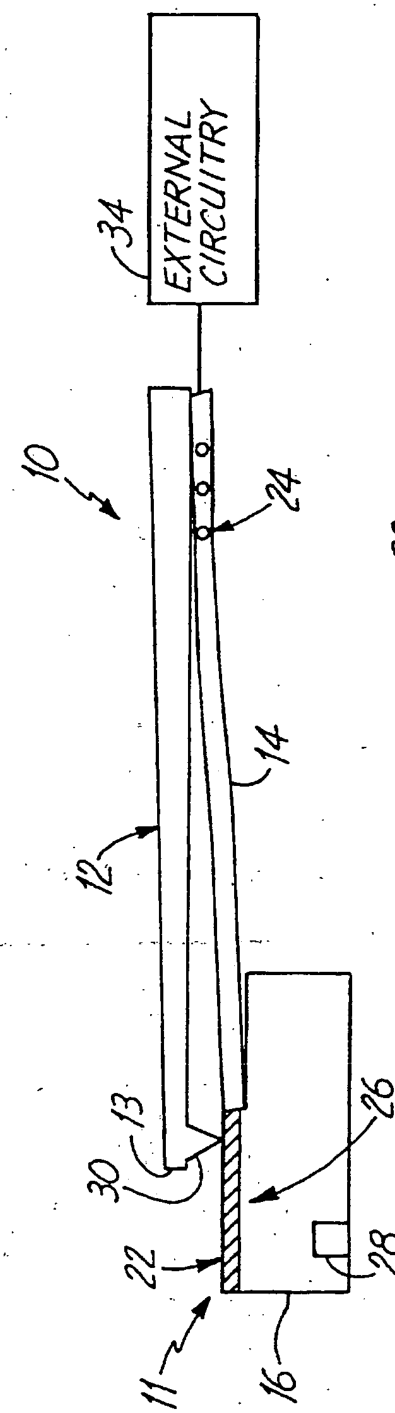
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Fig. 3

of carrier material 18. This helps to provide flex cable 14 with desired pitch and roll stiffnesses. The specific features of gimbal insert 22 can be tailored to achieve the desired pitch and roll stiffnesses in a number of ways. For example, the dimensions of gimbal insert 22 can be selected to aid in obtaining particular pitch and roll stiffnesses. Also, the specific placement of gimbal insert 22 on carrier material 18 can be changed somewhat to tailor the stiffnesses. Further, the material used for gimbal insert 22 can be changed to utilize the different stiffening properties of different materials.

FIG. 3 is a side view illustrating further advantageous features of the improved flexure of the present invention. As is illustrated diagrammatically in FIG. 3, flex cable 14 is laser welded, using welding points 24, to suspension 12. However, in other embodiments, flex cable 14 is attached to suspension 12 using adhesives or other attachment mechanisms. Also as shown in FIG. 3, suspension 12 includes load tab on extension 13, which applies a pre-load force to flex cable 14 in order to thereby provide a pre-load force to slider 16. As in known in the art, this pre-load force aids in "flying" slider 16 over magnetic disc 32 during operation of the disc drive date storage system. However, it must be noted that the illustration in FIG. 3 is merely an example, and is not intended to represent any particular slider orientation relative to disc 32 during operation. FIG. 3 also illustrates magnetic data head 28 on slider 16, which is electrically coupled via traces 20 and bond pads (not shown) on a surface of slider 16 to external circuitry 34 located, for example, on the arm or elsewhere. External circuitry 34 cooperates with magnetic data head 28 to read/write data from/to disc 32. It must be noted that more than one data head 28 can be located on slider 16. Further, the position of data head 28 on slider 16 shown in FIG. 3 is merely illustrative and is not intended to imply any preferred data head location.

In the flex suspension design of the present invention, flex cable 14 serves several functions. It provides the electrical connections between magnetic head 28 (through bond pads on the slider) and external circuitry 34. It also provides the gimbal structure for the flexure. The specific design of the gimbal incorporates features which minimize large RSA and PSA sigmas, and enables designers to tailor the pitch and roll stiffnesses.

Gimbal insert 22 provides the structure which enables designers to tailor the pitch and roll stiffnesses by adding the stiffness of insert 22 to the existing stiffness of electrical traces 20 and to the existing stiffness of carrier material 18. Thus, the present invention provides a highly advantageous improvement over the prior art, in that it decouples the resistivity requirements of electrical traces 20 from the stiffness requirements of insert 22. Without gimbal insert 22, either the stiffness of flex cable 14 would be heavily influenced by the resistivity requirements of electrical traces 20, or the resistivity of electrical traces 20 would be heavily influenced by the stiffness requirements of flex cable 14.

Another advantageous feature of the present invention is that use of gimbal insert 22 provides an integrated electrical interconnect gimbal structure which is substantially coplaner with upper surface 17 of slider 16, since gimbal insert 22 provides features for attachment of the slider. A significant contribution of the present invention relates to the fact that electrical traces 20 are made coplaner to the gimbal assembly (i.e. gimbal insert 22). By maintaining the coplanarity of the electrical connections, less torsional and bending moments will be generated on the slider. The effective vertical offset distances between the gimbal structure and the electrical connections becomes virtually zero, compared to a few mils as exists in many conventional designs.

In preferred embodiments the metallic material used for gimbal insert 22 is significantly less sensitive to temperature and humidity than is the polyamide or other material used as carrier 18. Thus, insert 22 provides rigidity, which is relatively insensitive to exposure to temperature extremes and humidity, to flex cable 14. Another advantage provided by gimbal insert 22 is that, when a metallic material is used, electrical grounding of slider 16 to flexure 12 (through insert 22) is ensured. Also, the polyamide material of carrier 18 provides additional damping to the gimbal structure, thus reducing gimbal vibrations.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A flexure for supporting a magnetic head carrying slider, the flexure comprising:

flexible circuit means for electrically coupling the magnetic head, and supporting the slider; and

load bearing means for supporting the flexible circuit means.

2. A flexure for supporting a magnetic head carrying slider, the flexure comprising:

load beam means for supporting a load; and

a flexible circuit comprising:

means for carrying electrical trace means supported by the means for carrying for electrically coupling to the magnetic head carried by the slider; and

gimbal insert means supported by the means for carrying and coupled to the load beam means.

3. The flexure of claim 2 wherein the gimbal means is substantially coplanar with the electrical trace means.

4. A combined gimbal flexure and electrical interconnect assembly for attachment to a disc drive actuator load beam and for supporting a magnetic head carrying slider, comprising:

means for carrying extending from the load beam to a location proximate the slider;

means for electrically conducting extending from the load beam to a location proximate the slider and being attached to the means for carrying for electrically coupling the magnetic head carried by the slider to external circuitry; and

means for stiffening extending from the load beam to a location proximate the slider and being attached to the means for carrying.

5. The combined gimbal flexure and electrical interconnect assembly of claim 4 wherein the means for carrying is substantially coplanar with the means for electrically conducting.

6. An actuator for supporting a magnetic head carrying slider, the actuator comprising:

a suspension member; and

a flex cable comprising:

means for carrying;

means for gimbaling coupled to the means for carrying, the suspension member and the slider;

means for electrically conducting supported by the means for carrying.

7. The actuator of claim 6 wherein the means for electrically conducting is substantially coplanar with the means for gimbaling.

* * * * *

APPENDIX D

US005795162A

United States Patent [19]

Lambert

[11] **Patent Number:** 5,795,162

[45] **Date of Patent:** Aug. 18, 1998

[54] **RF FLEX CIRCUIT TRANSMISSION LINE AND INTERCONNECTION METHOD**

[75] Inventor: **William R. Lambert**, Morris, N.J.

[73] Assignee: **Lucent Technologies, Inc.**, Murray Hill, N.J.

[21] Appl. No.: **623,087**

[22] Filed: **Mar. 28, 1996**

[51] **Int. Cl.**^{6} **H01R 9/09**

[52] **U.S. Cl.** **439/63**; 439/67

[58] **Field of Search** 439/63, 67, 581

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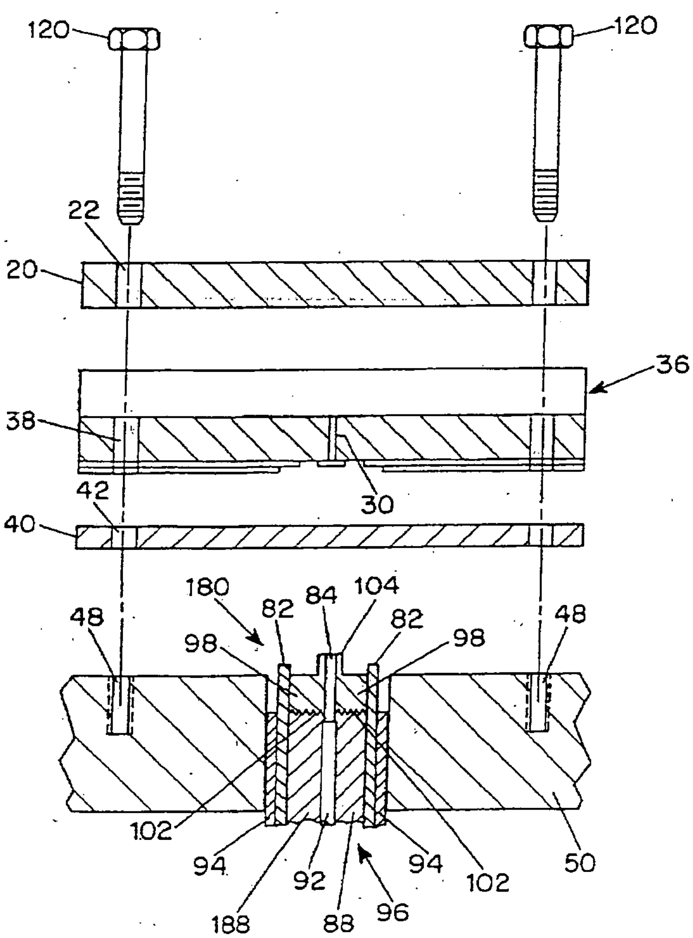
Primary Examiner—Gary P. Paumen
Assistant Examiner—T. C. Patel

[57] **ABSTRACT**

An interconnection system comprises a circuit board having signal conductors for carrying electrical signals. The circuit board includes a plurality of contact pads coupled to each one of said signal conductors. An elastomeric compression interconnect is releasably disposed next to the contact pads of the circuit board. The elastomeric compression interconnect includes a composite material having magnetic, electrically conductive substantially spherical particles disposed in a nonconductive matrix material adapted to align into mutually isolated conductive chains. A radio frequency flex circuit is also releasably disposed next to the elastomeric compression interconnect. The flex circuit is made of a dielectric material and a bonding material exhibiting substantially low signal loss.

21 Claims, 4 Drawing Sheets



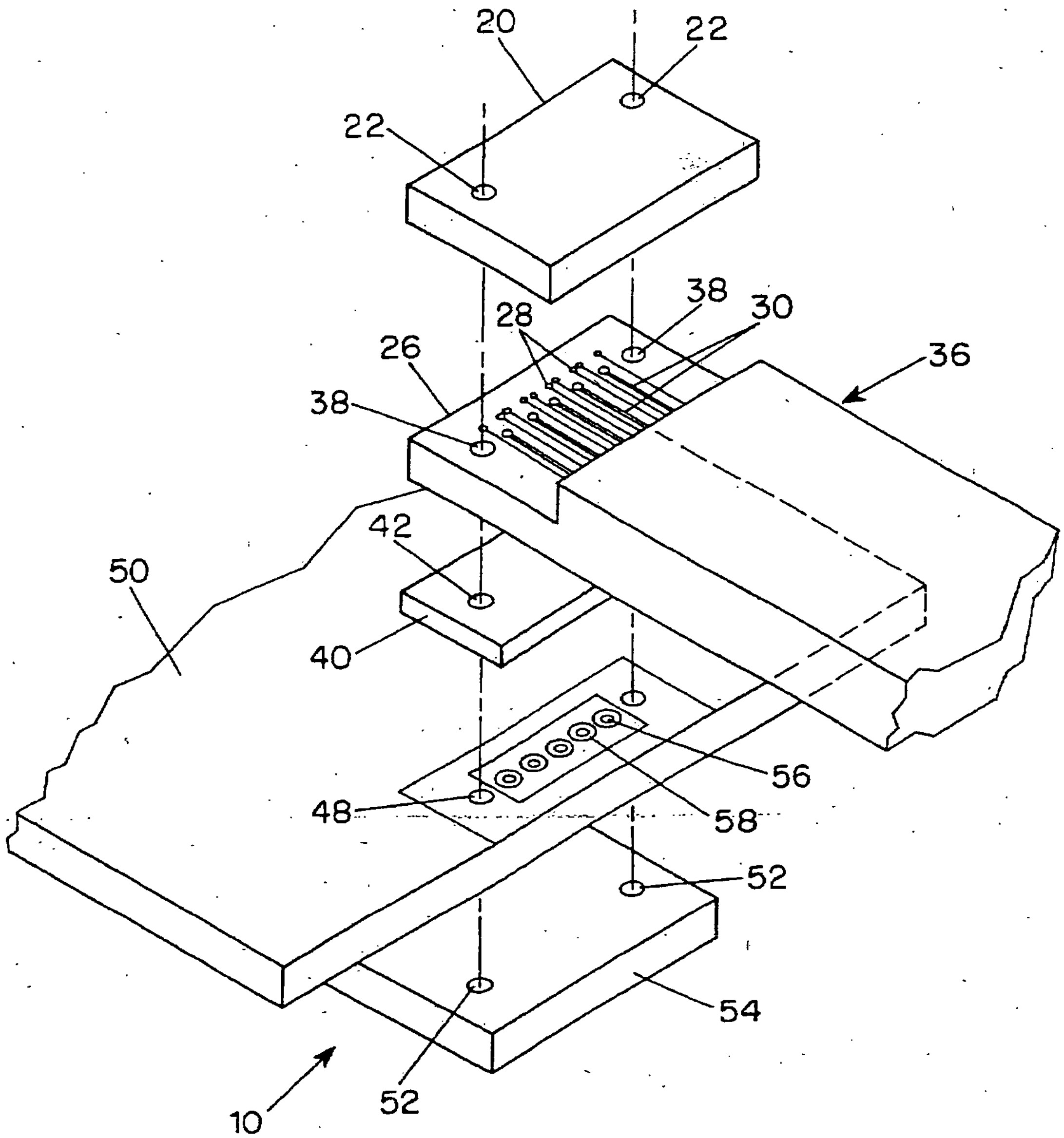


FIG. 1

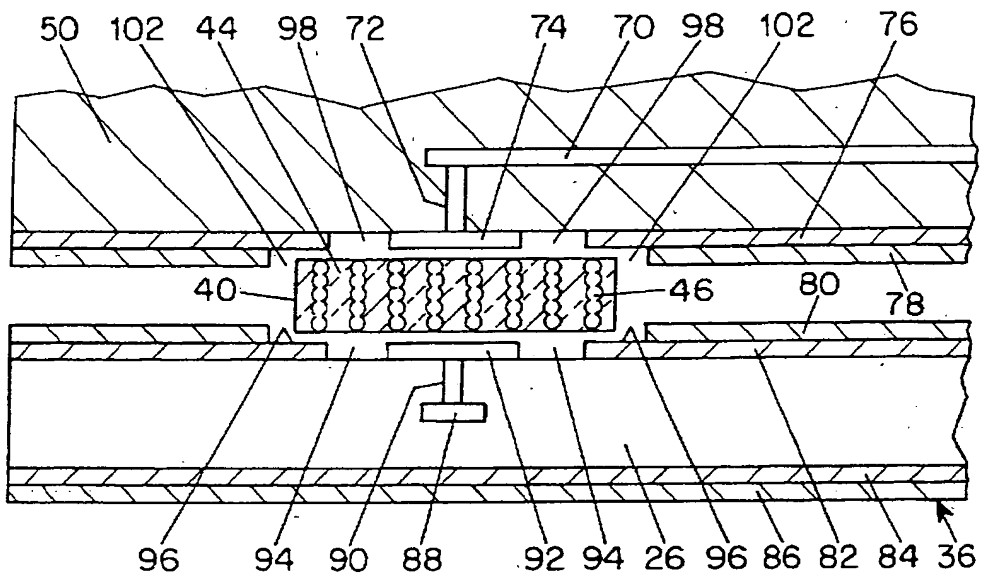

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FIG. 2a

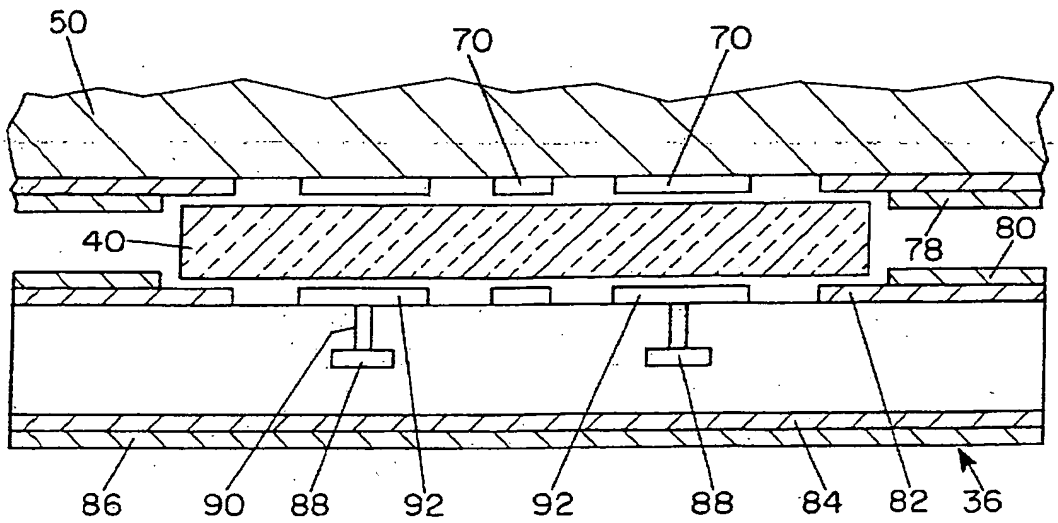
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FIG. 2b

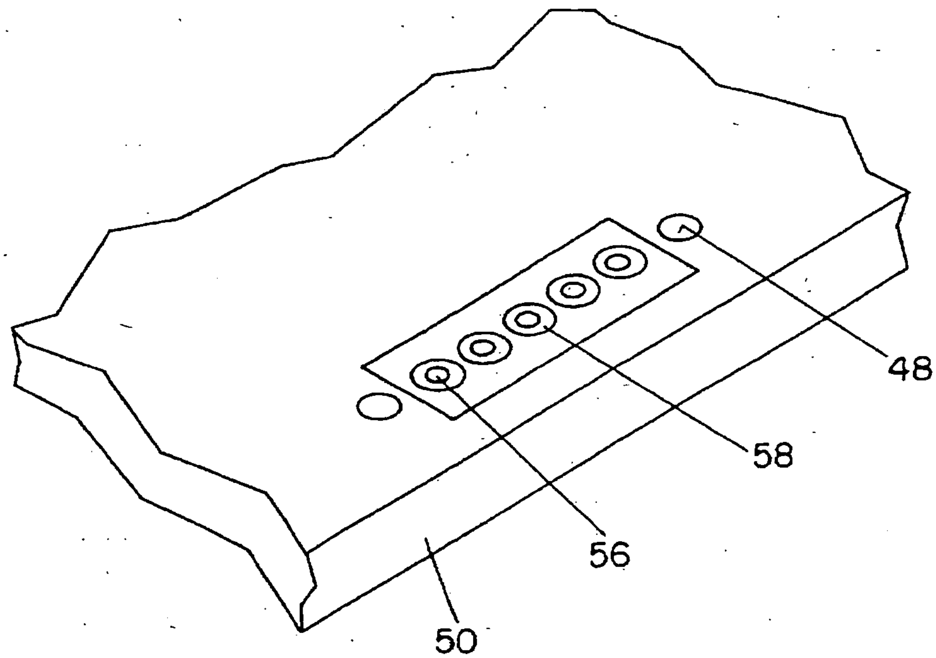

FIG. 3a

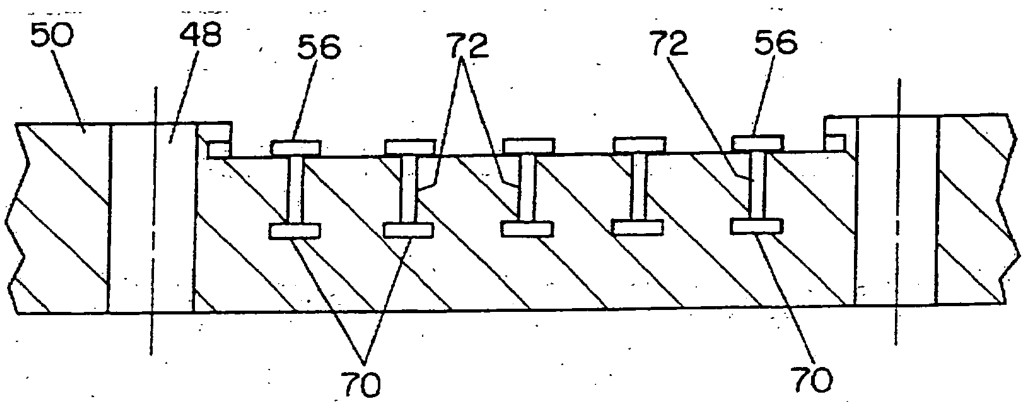

FIG. 3b

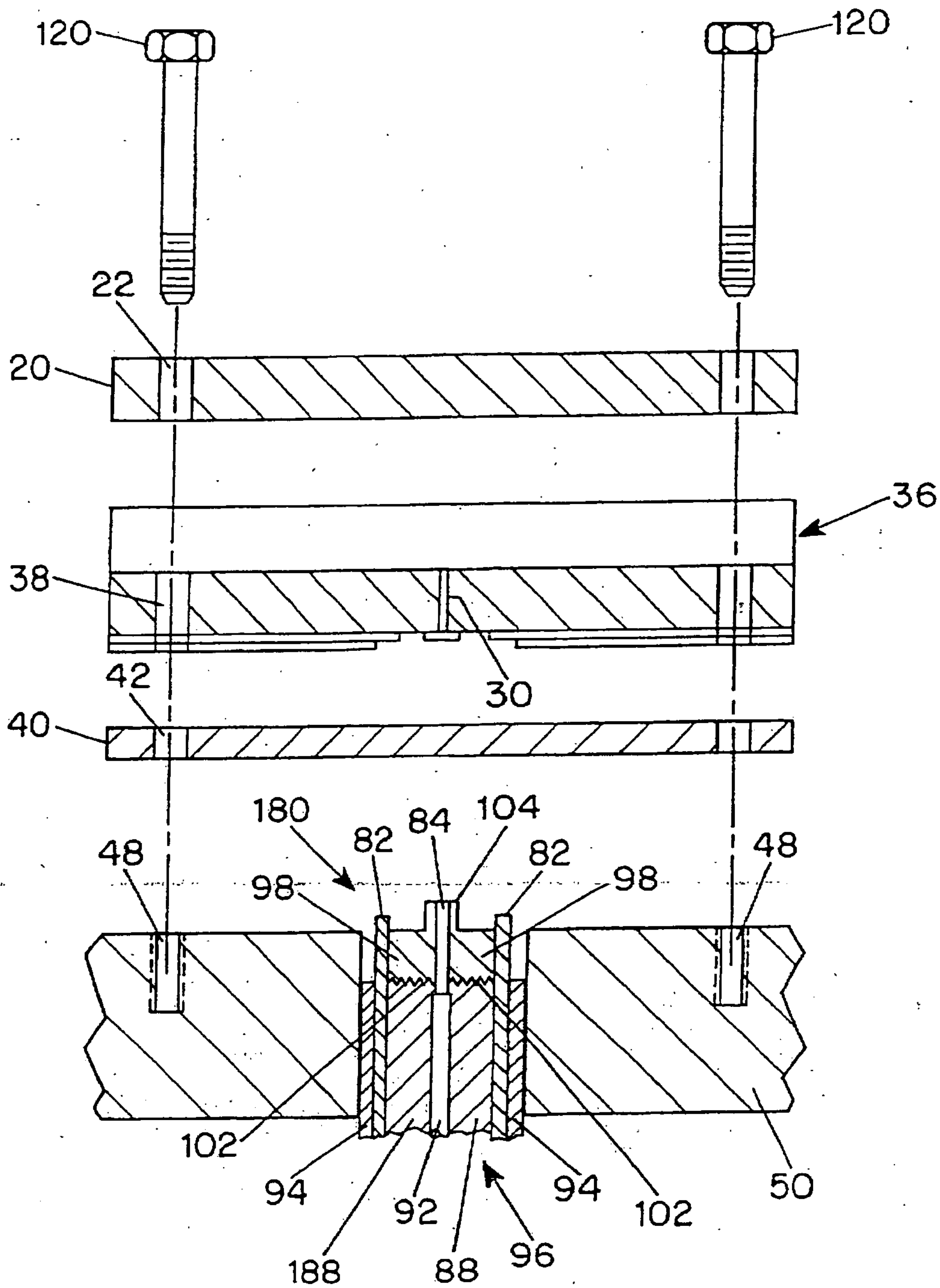
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FIG. 4

RF FLEX CIRCUIT TRANSMISSION LINE AND INTERCONNECTION METHOD

FIELD OF THE INVENTION

This invention relates generally to flexible transmission lines and more specifically to methods for interconnecting such lines to printed circuit boards.

BACKGROUND OF THE INVENTION

Many electronic applications require extensive radio frequency (RF) cabling. For example a typical RF section on the backplane of a wireless base station may consist of forty eight, approximately 24-inch long, coaxial cables. These coaxial cables form a point-to-point distribution fabric between the transmitter circuit packs and the switching circuit packs, and between the receiver circuit packs and the switching circuit packs—all employed in a wireless base station of a wireless communications system. A typical switching circuit pack has four RF connections: one to the transmitter; one to a first receiver; one to a second receiver; and one to a clock synchronization circuit. There may be at least twelve switching packs in each wireless base station. It will be appreciated that the number of coaxial cables employed to interconnect the RF components mentioned above may be substantially high. The cost of these coaxial cables contributes significantly to the overall cost of a typical RF distribution fabric.

Additional disadvantages associated with the use of coaxial cables are the space required to accommodate numerous cables, relatively low reliability and relatively high maintenance cost. Furthermore, as underlying electronic components of the circuit packs become smaller, the size of coaxial cables may become an impediment to miniaturization of the system. It should be noted that the above concerns with the use of coaxial cables in a RF distribution fabric of a wireless base station are also present in other applications that require the use of numerous cables.

Thus, there is a need for a system and a method that substantially eliminates disadvantages associated with the use of coaxial cables employed in RF distribution fabrics.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention an interconnection system for radio frequency RF applications may be employed. The interconnection system comprises a circuit board having signal conductors for carrying electrical signals. The circuit board includes at least one contact pad coupled to one of the conductors. A compression interconnect is employed to couple signal lines in the circuit board to signal lines in a radio frequency, RF flex circuit. The interconnect, which may be made of an elastomeric material, includes a first and a second outer surface. The first outer surface is releasably disposed next to the contact pad of the circuit board. The radio frequency RF flex circuit has at least one contact pad coupled to an embedded signal conductor. The contact pad is releasably disposed next to the second outer surface of the compression interconnect to make electrical connection between the signal conductors in the circuit board and the flex circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with

features, objects, and advantages thereof may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

FIG. 1 is an exploded view of a portion of an interconnection system comprising a RF flex circuit, an elastomeric interconnect and a printed circuit board in accordance with the present invention.

FIGS. 2*a* and 2*b* illustrate the side views of an interconnection system in accordance with the present invention.

FIG. 3 illustrates an example of a circuit board employed in an interconnection system in accordance to the present invention.

FIG. 4 illustrates a retrofit application of an interconnection system in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates an exploded view of one embodiment of the invention such as an interconnection system **10** that may be employed in a radio frequency (RF) distribution fabric. The interconnection system comprises an RF flex circuit **36**, a compression interconnect **40**, and a radio frequency (RF) board **50**.

Typically, RF board **50** may be a printed circuit board having a plurality of radio frequency signal lines or traces, as described in more detail in reference with FIGS. 3*a* and 3*b*, although the invention is not limited in scope in that respect. For example, circuit packs in a wireless base station such as transmitter and receiver and switching circuit packs contain numerous signal lines that carry radio frequency signals. Such signal lines, are usually made of copper and may be embedded within the material that forms the printed circuit board. In the alternative the signal lines may be disposed on the outer layer of the printed circuit board. As will be explained in more detail hereinafter, in reference with FIG. 4, existing circuit packs may employ coaxial cable connectors for coupling signal lines to coaxial cables. Thus, it is desired to replace such connectors with a retrofit connector that couples signals in the signal lines to elastomeric interconnect **40** as will be explained in more detail below.

In accordance with one embodiment of the invention, circuit board **50** is preferably disposed over a substrate **54**. This substrate may be made of a rigid material. For high frequency applications the substrate may be made of an insulating material such as plastic.

In an exemplary embodiment of the invention radio frequency signal lines of circuit board **50** may be coupled to compression interconnect **40** via contact pads **56**. As will be explained, compression interconnect **40** may be made of an elastomeric material. Such contact pads may also be coupled to signal lines embedded within the circuit board via through- holes **72** (FIG. 2*a*) as will be explained in more detail hereinafter. Advantageously, annular ground areas **58** may surround contact pads **56** and through-holes **72**.

Referring to FIGS. 1 and 2*a*, elastomeric compression interconnect **40** is advantageously positioned over circuit board **50**, such that holes **42** of compression interconnect **40** overlay holes **48** of circuit board **50** and holes **52** of substrate **54**. The design of elastomeric compression interconnects is well-known as described in the U.S. Pat. No. 5,045,249 issued to Jin et al. and in the U.S. Pat. No. 4,820,376 issued to Lambert et al., both of which are incorporated herein by reference. Basically electrical interconnections **46** are made by means of a layer or sheet medium comprising chains of

magnetically aligned, electrically conducting particles in a non-conducting matrix material 44. Electrically conductive, magnetic particles are aligned into essentially straight chains as resulting from application of a magnetic field in the z-direction of desired conductivity transverse to the x-y plane of interconnect 40. End particles of chains may preferably protrude from a surface of the medium, thereby enhancing electrical contact properties of the medium. Electrical interconnections 46 may be attached to contact pads disposed at both sides of compression interconnect 40.

In accordance with one aspect of the present invention, the high frequency characteristics of elastomeric compression interconnects such as 40 is one of the factors that is preferably considered in its manufacture. For example, an interconnection such as 40 may be made by first mixing a silicone resin material such as RTV615 with 10 volume percent gold-coated nickel spheres having a diameter of about 2 mils. The mixture is spread to form a layer having a thickness of approximately 10 mils. The free surface of the mixture may be left uncovered. A magnetic field having a strength of approximately 400 oersteds is then applied in a direction perpendicular to the layer while the adhesive is cured at approximately 100° C. Preferably the compression interconnect material such as 40 may transmit a signal at about 1.7 Gb/s (0.158 ns rise time) with 5.0% reflection or less.

Other types of elastomeric connector materials may include a pad array interconnect known as Matrix MOE connector, and FujiPolymer W-Series materials, which includes wires extending through the thickness of the elastomer. These wires are typically located on a regular grid.

It is noted that the present invention is not limited in scope to a particular kind of compression elastomeric interconnect. For example other suitable compression interconnects may be employed such as Interposer and Micro-Interposer brands manufactured by AMP. These products are micro-mechanical contacts which require 300 grams and 150 grams force per contact, respectively, to form a reliable interconnect. Other examples include EII and PAI brands manufactured by AUGAT. These products are designed for 50-mil centerline pad array interconnection. EII is constructed from a flexible circuit and utilizes through-hole technology, while PAI is made from miniature compression mountable spring plungers.

However, it is desired that the compression interconnect meet the electrical design specifications relating to the particular applications employed in connection with the present invention. For example, not all elastomeric compression interconnect materials are suitable for RF applications. Preferably, the magnetically aligned materials employed in the present invention and described previously, have shown to be advantageously useable at frequencies up to about 4 GHz—which is an approximate frequency limit for testing purposes.

A flex circuit 36 is positioned over compression interconnect 40, such that holes 38 of the flex circuit overlay holes 42, 48 and 52. Signal lines 30 are embedded within flex circuit 36 and are configured to carry radio frequency signals. The length of flex circuit 36 depends on requirements of the particular radio frequency RF distribution fabric to be implemented. Preferably, when the RF distribution fabric is implemented in a wireless base station of a wireless telecommunications system, the length of the flex circuit may be about 20 inches long.

Signal lines 30 are preferably made of copper, and are embedded in a flexible dielectric material 26. The loss of radio frequency signals carried in signal lines 30 depends on, among other things, the dielectric constant and the dielectric dissipation factor. In accordance with one aspect of the invention flex circuit 36 may advantageously include interstitial ground lines 28 positioned adjacent to signal lines 30, although the invention is not limited in scope in that respect. Advantageously, the use of ground lines 28 may substantially reduce cross talk between signal lines 30. Signal lines 30 and ground lines 28 are preferably situated between two ground planes disposed on the outer surface of dielectric 26. As it will be explained in more detail in reference with FIGS. 2a and 2b, contact pads for coupling conductors 47 and signal lines 30 are preferably situated on the one surface of flex circuit 36 positioned against compression interconnect 50. Finally, a cover 20 is positioned over flex circuit 36, such that holes 22 overlay holes 38. Cover 20 is advantageously made of an insulating material. A screw 120 (FIG. 4) may run through holes 22, 38, 42, 48 and 52, to attach the circuit board signal lines and the flex circuit signal lines via compression interconnect 40. It is noted that other suitable means of attachment, such as clamping or bonding may also be employed.

FIGS. 2a and 2b illustrate the side views of one embodiment of an interconnection system 10 in accordance with the present invention, although the invention is not limited in scope to this embodiment. As illustrated in FIG. 2a a flex circuit 36 is coupled to circuit board 50 via compression interconnect 40. Flex circuit 36 comprises a ground plane 84 disposed over the internal section of a solder mask layer 86. A dielectric layer 26 is disposed over ground layer 84. Dielectric layer 26 comprises a flexible substrate and is formed from multiple layers. An exemplary signal line 88 is preferably embedded within the dielectric layer. In this particular context, signal line 88 is positioned along an axis perpendicular to the plane of the paper. A ground layer 82 is disposed over dielectric layer 26. Ground layer 82 is configured so as to form openings 94. A contact pad 92 is disposed over dielectric 26, and is coupled to signal line 88 via a through-hole 90. Contact pad 92 is preferably made of gold-plated copper.

A solder mask layer 80 is disposed over ground layer 82, and is configured so as to form openings 96. Compression interconnect 40 is positioned over flex circuit 36 so as to make contacts with contact pad 92 and ground plane 82 through openings 96. Compression interconnect 40 is positioned to also make contact with circuit board 50 as described below.

Circuit board 50 may be a circuit pack employed in a wireless base station of a wireless telecommunications system, although the invention is not limited in scope in that respect. Thus, circuit board 50 may be a printed circuit board having radio frequency signal traces. Such signal traces may be disposed on the circuit board. In the alternative, as illustrated in FIG. 2a, signal lines 70 may be embedded within circuit board 50. In this particular context, signal line 70 is coupled to a contact pad 74 via a through hole 72. Circuit board 50 may preferably include a ground layer 76 disposed over the external surface of circuit board 50, covered by a mask layer 78. Ground layer 76 is configured so as to form openings 98. Likewise, solder mask layer 78 is configured so as to form openings 102.

As mentioned previously, signal lines 88 within dielectric 26 have preferably a substantially low signal loss. This signal loss is preferably in the order of 0.5 dB, or less, for a 20"-long flex circuit. However, signal losses of about 2 through 4 dB may be sufficiently acceptable. Flex circuit 36 is preferably made of a dielectric material with a dielectric

constant of about 2 through 4 and a dissipation factor of about 0.005 or less at 1 GHz.

To this end, dielectric 26 may be made of Kapton laminate in conjunction with Arcrylic Bondply both manufactured by DuPont. In accordance with one aspect of the invention, flex circuit **36** may be manufactured in two steps. During the first step, two dielectric layers of Kapton laminate are formed, with a thickness of approximately half of the final thickness of flex circuit **36**. On one of the dielectric layers signal lines **88** are formed. Thereafter during the second step, the other half of dielectric layer is bonded to the first half using the Arcrylic Bondply. Table 1 illustrates dielectric properties of Kapton and Acrylic Bondply in accordance with one aspect of the invention, although the invention is not limited in scope in this respect.

TABLE 1

	Dielectric Constant @ 1 MHz	Dissipation Factor @ 1 MHz
Kapton (polyimide)	3.6	0.02
Acrylic Bondply	3.6	0.02

In accordance with another aspect of the invention, flex circuit **36** may be made of Gore-Flex laminate and Speedboard J Bondply, both manufactured by GoreTex. Table 2 illustrates dielectric properties of these materials.

TABLE 2

	Dielectric Constant @ 1 MHz	Dissipation Factor @ 1 MHz
Gore-Flex laminate	3.1	0.005
Speedboard J Bondply	2.3	0.004

In accordance with another aspect of the invention, it is desirable to make flex circuit **36** of one dielectric material instead of two. This results in substantially better signal characteristics. One approach to manufacture a flex circuit with one dielectric, in accordance with one aspect of the invention, is to fabricate flex circuits using thermoplastic materials. Thin plys of thermoplastic substrate covered by a copper layer is preferably employed, onto which copper signal lines are then patterned, prior to a bonding or laminating process. The thermoplastic plys may then be advantageously laminated to produce a structure in which the signal conductors are embedded within a homogenous dielectric. An example of such thermoplastic material is Vectra brand dielectric manufactured by Hoechst-Celanese. Table 3 illustrates the electrical characteristics of Vectran, which is a liquid crystal polymer (LCP) product.

TABLE 3

	Dielectric Constant @ 1 GHz	Dissipation Factor @ 1 GHz
Vectran (liquid Crystal Polyemer)	2.9	0.0025

Finally, other thermoplastic materials that may be suitable for use as flex circuit **36** are illustrated in Table 4 below.

TABLE 4

	Dielectric Constant @ 1 GHz	Dissipation Factor @ 1 GHz
TPX (polymethyl pentene)	2.2	0.00007
Noryl (polyphenylene oxide)	2.8	0.0009
Propylux (polypropylene)	2.3	0.002
Lennite (polyethylene)	2.5	0.0006

FIG. 2*b* illustrates another embodiment of interconnection system **10** showing a plurality of signal lines **88** in flex circuit **36** coupled to signal lines **70** in circuit board **50**. It is noted that although exemplary illustrations of flex circuit **36** include one layer of signal lines, it may be desirable to have multiple layers of signal lines for some applications. Furthermore, circuit board **50** may also be made of multiple layers of signal traces.

FIGS. 3*a* and 3*b* illustrate an embodiment of circuit board such as **50** in more detail. FIG. 3*a* is a perspective view of circuit board **50** as described in reference with FIG. 1. FIG. 3*b* is a side view illustration of circuit board **50** having a plurality of signal lines **70** embedded within the circuit board and coupled to contact pads **56** via through holes **72**.

As mentioned before, many existing circuit boards employed in radio frequency related applications incorporate coaxial pin connectors that cannot directly be used in conjunction with an elastomeric compression interconnect so as to couple radio frequency signal lines to a flex circuit. In accordance with one embodiment of the invention, it is desirable to retrofit such coaxial connectors so that an interconnection system described herein may be implemented. FIG. 4 illustrates one such retrofit application, although the invention is not limited in scope in that respect.

FIG. 4 illustrates a circuit board such as **50** having an existing coaxial pin connector **96**, which includes a signal pin **92** and annular grounding receptacle **94**. In one embodiment of the invention, coaxial pin connector is advantageously modified such that insulating sections **188** are pressed downwardly to below lines **102**. An adaptor plug **180** is then inserted over coaxial pins **92** and within the annular grounding receptacle **94** of the coaxial connector. Plug **180** includes a signal connector **84** topped by a contact pad **104**. Signal connector **84** couples detachably to pin **92**. Adaptor plug **180** includes an annular ground ring **82** that couples to ground pins of coaxial connector **96**. The annular ground ring **82** along with contact pad **104** may then be coupled to compression interconnect **40** to form an interconnection system with flex circuit **36** as described above.

Thus, the present invention allows substantial cost savings for implementing radio frequency distribution fabrics over prior art interconnection systems. Furthermore, the present invention allows the possibility of substantially miniaturizing such radio frequency distribution fabrics.

The foregoing merely illustrates the principles of the inventions. It will thus be appreciated that those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are thus within its spirit and scope.

We claim:

1. An interconnection system comprising:
   - a circuit board having signal conductors for carrying electrical signals said signal conductors being embedded within said circuit board;
   - at least one contact pad coupled to one of said signal conductors via a conduction element defining a through-hole;

a ground layer disposed over portions of said circuit board such that an opening is formed between said ground layer and said contact pad;

a compression interconnect having a first and a second outer surface, said first outer surface of said interconnect releasably disposed next to said contact pad of said circuit board;

a radio frequency flex circuit having at least one contact pad coupled to a signal conductor, said contact pad releasably disposed next to said second outer surface of said elastomeric compression interconnect; and

a plurality of interstitial ground lines positioned adjacent said signal conductor of said flex circuit.

2. An interconnection system in accordance with claim 1, wherein said radio frequency flex circuit further comprises a dielectric material and a bonding material each having a dielectric constant in a range of about 2 to about 4 and a dissipation factor less than about 0.005 at 1 GHz.

3. An interconnection system in accordance with claim 2, wherein said dielectric material is a polyimide laminate and said bonding material is an acrylic bonding material.

4. An interconnection system in accordance with claim 3, wherein the dielectric constants of said polyimide laminate and said acrylic bonding material at about 1 MHZ is about 3.6, and the dissipation factors of said polyimide laminate and said acrylic bonding material at 1 MHZ is 0.02.

5. An interconnection system in accordance with claim 2, wherein said dielectric material is a Gore-Flex laminate and said bonding material is a Speedboard J Bondply bonding material.

6. An interconnection system in accordance with claim 5, wherein said laminate and said bonding material have a dielectric constant of less than about 3.1 at about 1 GHz and a dissipation factor of less than about 0.005 at about 1 GHz.

7. An interconnection system in accordance with claim 1, wherein said radio frequency flex circuit comprises a thermoplastic substrate having a plurality of signal lines laminated within said substrate.

8. An interconnection system in accordance with claim 7, wherein said thermoplastic substrate has a dielectric constant of about 2.9 and a dissipation factor of about 0.0025 at 1 GHz.

9. An interconnection system in accordance with claim 2, wherein said radio frequency flex circuit comprises a first and second section made of said dielectric material, said first section adapted to contain a plurality of signal lines, said first and second section bonded together by said bonding material.

10. An interconnection system in accordance with claim 9, wherein said signal lines are made of copper.

11. An interconnection system in accordance with claim 10, wherein a ground line is disposed adjacent to said signal line.

12. An interconnection system in accordance with claim 1, wherein said compression interconnect comprises an elastomeric composite material.

13. An interconnection system in accordance with claim 12, wherein said elastomeric interconnect further comprises a composite material having substantially spherical particles exhibiting substantially magnetic properties, disposed in a nonconductive matrix material adapted to define said first and second outer surface, wherein said magnetic particles are further adapted to align into mutually isolated chains.

14. An interconnection system in accordance with claim 13, wherein said isolated chains protrude from said matrix material at said at least one outer surface.

15. An interconnection system in accordance with claim 13, wherein said elastomeric compression interconnect is securely attached to said circuit board by a securing means.

16. An interconnection system in accordance with claim 13, wherein said elastomeric compression interconnect is securely bolted to said circuit board by screws.

17. An interconnection system comprising:

a circuit board having signal conductors for carrying electrical signals, said signal conductors being embedded within said circuit board;

a plurality of contact pads, each coupled to one of said conductors via a conduction element defining a through-hole;

a ground layer disposed over portions of said circuit board such that an opening is formed between said ground layer and said contact pad;

an elastomeric compression interconnect having a first and a second outer surface, said first outer surface of said interconnect releasably disposed next to said contact pads of said circuit board;

a radio frequency flex circuit having a plurality of contact pads each coupled to a signal conductor via a through-hole, said contact pads releasably disposed next to said second outer surface of said elastomeric compression interconnect, said flex circuit further comprises a dielectric material and a bonding material each having a dielectric constant in a range of about 2 to about 4 and a dissipation factor of less than about 0.005 at 1 GHZ; and

a plurality of interstitial ground lines positioned adjacent said signal conductor of said flex circuit.

18. An interconnection system in accordance with claim 17, wherein said elastomeric compression interconnect further comprises a composite material having magnetic electrically conductive substantially spherical particles disposed in a nonconductive matrix material adapted to define said first and second outer surface, wherein said magnetic particles are further adapted to align into mutually isolated chains.

19. An interconnection system in accordance with claim 18, wherein said circuit board, said interconnect material and said flex circuit are attached together so as to form electrically conductive paths between signal lines in said circuit board and corresponding signal lines in said flex circuit.

20. An interconnection system comprising:

a circuit board having signal conductors for carrying electrical signals;

annular grounding receptacle separated from each of said signal conductors of said circuit board by an insulating section;

an adaptor plug disposed over said signal conductor of said circuit board and against said grounding receptacle, said adaptor plug comprising a signal connector coupled to a contact pad, said signal connector adapted to couple detachably to said signal conductor of said circuit board, said adaptor plug further comprising an annular ground ring coupled to said annular grounding receptacle;

a compression interconnect having a first and a second outer surface, said first outer surface of said interconnect releasably disposed next to said contact pad of said circuit board; and

a radio frequency flex circuit having at least one contact pad coupled to a signal conductor, said contact pad releasably disposed next to said second outer surface of said elastomeric compression interconnect.

21. An interconnection system in accordance with claim 20, wherein said flex circuit is configured to include a

plurality of contact pads each coupled to a signal conductor within said flex circuit via a through-hole, said contact pads releasably disposed next to said second outer surface of said elastomeric compression interconnect, said flex circuit further comprises a dielectric material and a bonding material each having a dielectric constant in a range of about 2 to about 4 and a dissipation factor less than about 0.005 at 1 GHz.

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Appendix E

LIST OF CASES CITED

In re Donaldson Co., 29 U.S.P.Q.2d 1845 (Fed. Cir. 1994).

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